

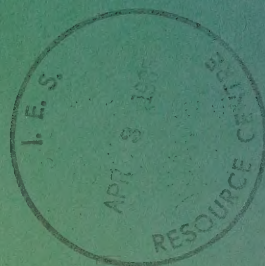
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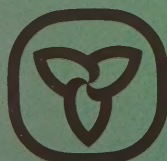
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REPORT FOR THE REGIONAL MUNICIPALITY OF WATERLOO ON FUTURE WATER SUPPLY

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Deputy Minister

DRAFT DOCUMENT FOR DISCUSSION

REPORT
FOR
THE REGIONAL MUNICIPALITY OF WATERLOO
ON
FUTURE WATER SUPPLY

EXISTING WATER RESOURCES FEASIBILITY STUDY

LAKE SOURCE OF SUPPLY

SEWER SYSTEM

COST OF SUPPLY

WATER TREATMENT

GROUND WATER SOURCE FEASIBILITY

WATER RESOURCES DEVELOPMENT ALTERNATIVES

GROUND WATER SOURCE FEASIBILITY

WATER RESOURCES DEVELOPMENT

CONCLUDING STATEMENT

APPENDIX A - TECHNICAL DATA

MINISTRY OF THE ENVIRONMENT

July 1974



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TABLE OF CONTENTS

	<u>Page #</u>
<u>SUMMARY</u>	iii
<u>INTRODUCTION</u>	1
<u>WATER REQUIREMENTS</u>	4
PROJECTED DEMANDS OF REGION	4
PERENNIAL YIELD OF AQUIFERS	4
REQUIREMENTS FROM AYR RESERVOIR	5
<u>For Ground Water Supply Plus Ayr</u> <u>Reservoir Recharge</u>	5
<u>For Ground Water Supply Plus Ayr</u> <u>Reservoir Direct Treatment</u>	6
<u>AYR RESERVOIR SOURCE OF SUPPLY</u>	7
RESERVOIR DESCRIPTION	7
RESERVOIR YIELD	7
FLOOD CONTROL BENEFITS	8
TREATMENT STUDIES	8
<u>For Direct Use</u>	8
<u>For Ground Water Recharge</u>	8
<u>GROUND WATER RECHARGE FEASIBILITY STUDIES</u>	9
<u>LAKE SOURCES OF SUPPLY</u>	12
<u>COST ESTIMATES</u>	14
COST CRITERIA	14
AYR RESERVOIR	15
GROUND WATER SUPPLY PLUS	
AYR RESERVOIR DIRECT TREATMENT	15
GROUND WATER SUPPLY PLUS	
AYR RESERVOIR RECHARGE	16
<u>CONCLUDING STATEMENT</u>	20
<u>APPENDIX A: Treatability Study</u>	21

LIST OF TABLES AND FIGURES

TABLES

Table 1	Population Projections 1976-1996	22
Table 2	Annual Water Consumption Projections 1976-1996	23
Table 3	Comparative Costs	24

FIGURES

Figure 1	Ground Water Supply Plus Ayr Reservoir Direct Treatment Alternative	25
Figure 2	Ground Water Supply Plus Ayr Reservoir Recharge Alternative	26
Figure 3	Areas Investigated for Feasibility of Ground Water Recharge	27
Figure 4	Roseville Area Recharge - Model Location Map	28
Figure 5	Pipeline Water Supply Systems Lake Erie and Lake Ontario Alternatives	29
Figure 6	Pipeline Water Supply System Lake Huron Alternative	30

SUMMARY

The former Ontario Water Resources Commission, in 1966, completed a report on water supplies for the Waterloo-South Wellington Counties area entitled "Middle Grand River Regional Water Supply Study" which evaluated water requirements for the area in light of forecasts of future development. The general conclusion reached was that ground water may not be available in sufficient quantities to accommodate the expected growth and anticipated demands in the Waterloo area by 1980 and that additional water, either to supplement or replace the available ground water supply, would be required.

A multi-disciplinary team was assembled by the Provincial Treasury Board Secretariat to review water management of the entire Grand River watershed. A report was presented in November 1971 entitled "Review of Planning for the Grand River Watershed". Three external sources of water supply and a number of internal sources were considered.

Subsequently, the Ministry of the Environment prepared and presented a report of the various water supply alternatives to the Regional Municipality of Waterloo in December 1973. The data and cost estimates have been reviewed and updated including further investigation and costs for an artificial ground water recharge scheme. This report now presents this information for review by the Regional Municipality. No preference has been suggested for any alternative at this time.

The projected 2001 population for the Kitchener-Waterloo-Cambridge area (KWC) is 575,000 persons. Based on this, it is estimated that the 2001 average daily water demand will be 69 million gallons. However, only half of this can be obtained from ground water supplies. By 1982, the demands will likely exceed the ground water capacity.

To meet the projected demands, five basic alternatives are presented.

Two alternatives incorporate a dam and reservoir on the Nith River near the Village of Ayr. Since construction would take three years and hearings and land acquisition could take a similar length of time, six years should be allowed for this project. Water from the reservoir would either be pretreated then used in an artificial ground water recharge system or treated in a conventional water treatment plant and supplied directly to the service area. Either of these systems would be used to complement the existing supplies.

However, before a final decision could be made on the feasibility and actual cost of the recharge project considerably more information would be needed. The consultant estimated that a period of 2.5 years at an approximate cost of \$460,000 is required for this further work.

A value has been assigned to the benefits that would be realized by the consumer if softer water were available. This value has been referred to as a softening charge for the purposes of estimating the costs.

Three lake oriented water supply schemes incorporating a large conventional water treatment plant at the lake and a pipeline to the service area are also suggested. The three sources are Lake Erie, Lake Huron and Lake Ontario. The type of treatment and the quality of the treated water would be essentially the same for each source.

For the Lake Erie scheme, costs were also developed for supply of the Nanticoke/Brantford areas since these could be served by the same pipeline.

The annual charges for operation and maintenance have been developed for each alternative.

Table 3 of the report summarizes the costs. The two reservoir alternatives suggest the most economic advantage and the Lake Erie system is the least costly of the pipelines. However, in comparing the costs, it must be realized that each alternative has its own advantages and disadvantages. In arriving at a final conclusion, an environmental assessment would be needed to identify the benefits and impact of the systems.

INTRODUCTION

The following outlines the involvement of the former Ontario Water Resources Commission and recently the Ministry of the Environment in the development of proposals relative to the provision and operation of major water works to serve the Regional Municipality of Waterloo.

Subsequent to the formation of the OWRC, numerous hydrogeologic and ground-water surveys were carried out and reports prepared by the Commission for several municipalities within the former County of Waterloo. In 1966, a publication entitled "Water Resources Survey of the County of Waterloo" was prepared by the Commission and provided an inventory of all water supply, pollution control and refuse disposal sites in the County. More than seventy-five reports have been published by many agencies dealing with ground and surface water, its quality, availability, use, improvement and deterioration in the area.

Realizing that potential development in the area would likely create problems with respect to the availability of water, the Commission, in 1966, completed a report on water supplies for the Waterloo-South Wellington Counties area entitled "Middle Grand River Regional Water Supply Study" which evaluated water requirements for the area in light of forecasts of future development. The general conclusion reached was that ground water may not be available in sufficient quantities to accommodate the expected growth and anticipated demands in the Waterloo area by 1980 and that additional water, either to supplement or replace the available ground water supply, would be required. In addition to the problem of water supply, there was considerable emphasis on the inadequacy of the Grand River to provide adequate dilution to effluents from waste disposal facilities. These conclusions established the basic criteria for subsequent water supply studies undertaken by the Commission.

Shortly after the 1966 report was completed, Ontario Hydro acquired property at Nanticoke, Ontario for a proposed generating station and The Steel Company of Canada Limited announced plans to construct a steel mill in Nanticoke on property west of the Hydro Generating Station. Subsequently, a Haldimand-Norfolk planning study was initiated by the Government in anticipation of increasing development pressures in the two counties.

In the late 1960's, a consulting engineering firm was engaged to estimate the cost of an area water supply system in order that information could be placed before the area municipalities for their consideration. On July 14, 1970, a meeting was held in Kitchener with representatives of the various large municipalities attending, including the Cities of Brantford, Galt, Kitchener and Waterloo and the Towns of Paris, Preston and Hespeler. Subsequently,

at the request of the municipalities, a tentative rate proposal for the supply of water was submitted to the municipalities on August 24, 1970. Lake Erie was assumed as the source of water supply for the Kitchener-Waterloo-Galt-Preston-Hespeler complex, utilizing intake facilities at the Ontario Hydro location in Nanticoke.

As a result of increasing concern of Provincial and Municipal agencies, the need for an all-encompassing water management policy for the complete Grand River watershed became apparent. A multi-disciplinary team was assembled by the Provincial Treasury Board Secretariat late in 1970. In November, 1971, the results of this study were presented in the form of a report entitled "Review of Planning for the Grand River Watershed".

This report considered three external sources of water supply; namely, Lakes Erie, Huron and Ontario. Various pipeline alternatives were investigated. Internal sources of water supply considered for the Kitchener-Waterloo-Galt-Preston-Hespeler complex were the proposed West Montrose, Ayr and Barrie Hill reservoirs, the Grand River and ground water. Some twenty-four recommendations were formulated with emphasis being placed on more future studies.

In 1972, a joint committee was set up to consider and co-ordinate implementation of the Treasury Board Report. A feasibility study for artificial ground-water recharge was initiated by the Ministry.

Test drilling and infiltration tests have been undertaken to provide data on hydrogeology and permeability of the deposits and preliminary estimates have been made on the suitability of surface materials for artificial recharge.

As a result of several Liaison Committee meetings between the Regional Municipality of Waterloo and the Ministry of the Environment, the Ministry presented a report of the various alternatives in December 1973. This report now presents the basic alternatives for further review by the Regional Municipality. The five basic alternatives being pipelines from three different lake sources, ground-water plus recharge of Ayr Reservoir waters and ground-water plus direct treatment of Ayr Reservoir water. The data and cost estimates have been reviewed and updated and the costs for the recharge scheme have been included. No preference has been suggested for any alternative at this time.

For all of the schemes the basic elements have been designed on the basis of a 25 year design period, 1976-2001.

An environmental assessment of the project will be required due to the scale and nature of the development contemplated. A general assessment of the options will require a few months time probably prior to further development of the project. Later, a detailed assessment of the selected alternative will be required as part of the design phase. The assessment may take one half year.

PATENT REQUIREMENTS

Land acquisition for any alternative may be difficult due to the scope and the many owners that will be involved. If expropriation becomes necessary, public hearings will be required. Also an environmental hearing will be required to review the environmental assessment and the specific site and route locations.

The peak population projections for the two areas are 200,000 persons and 244,000 persons, respectively. Table 1 summarizes the population of the population for the two areas and two areas for the years 1975 to 1995.

The anticipated water requirements for the same time periods are listed in Table 2. The peak water, without allowance for a two day water demand has been selected for use in the design shown in the report.

RECOMMENDED TYPE OF ACTIONS

The Treasury Board report "Review of Planning for the Grand River Water Supply, 1971" estimated that between 20.5 and 25.5 MGD of surface water was available to the municipality from existing public developed resources. In the Wychemer-Waterloo and Cambridge areas. At 1975, total capacity is 2 and 11.5 MGD of water in the Wychemer-Waterloo area and 12.5 MGD in the Cambridge area.

The possibility of these estimates over a long-term of projected data were in design and re-evaluation were undertaken in the Wychemer-Waterloo area by International Water Supply Ltd. on behalf of the Regional Municipality of Waterloo in 1975. The capacity was in a 100 years plan after considering the Grand and Kuy's River area as shown in the (1975).

In 1975, the report and a further re-evaluation by Wilcoy Ltd. showed the available water supply of 20.5 MGD. (2.5 MGD is the Wychemer-Waterloo area and 18.0 MGD is the Cambridge area). The Regional Municipality of Waterloo has a study in progress to review the field of water in the Cambridge area.

The Ministry's estimate of the availability of ground water potential based on the 1975 report may be summarized as follows:

Available Capacity	Estimated Time of Developed Peak Demand	Present Capacity	Total Capacity
Cambridge	11.5 MGD	1.5 MGD	13.0 MGD
Wychemer	12.5 MGD	Water Review	12.5 MGD
TOTAL	24.0 MGD	1.5 MGD	25.5 MGD

NOTE: A "Water Review" and there may be some ground water in the area of the Grand River area. The design shown in the report is based on the design shown in the report.

WATER REQUIREMENTS

PROJECTED DEMANDS OF REGION

The projected populations for the urban and industrial areas have been estimated for the Kitchener-Waterloo-Cambridge Area (KWC) and the Nanticoke-Brantford Area (N/B). The 2001 projected populations for the two areas are 575,000 persons and 284,000 persons respectively. Table 1 summarizes the breakdown of the population for the total area and two areas for the years 1976 to 1996.

The anticipated water consumptions for the same time period are listed in Table 2. The peak factor, ratio of maximum day to average day demands has been assumed to be 1.6 for design purposes in the report.

PERENNIAL YIELD OF AQUIFERS

The Treasury Board report "Review of Planning for the Grand River Watershed", 1971, estimated that between 24.8 and 29.5 MGD of ground water was available to the megalopolis from existing wells developed in aquifers in the Kitchener-Waterloo and Cambridge areas. Of this total between 12.8 and 17.5 MGD existed in the Kitchener-Waterloo area and 12.0 MGD in the Cambridge area.

The reliability of these estimates over a long-term or perennial basis were in doubt and re-evaluations were undertaken in the Kitchener-Waterloo area by International Water Supply Ltd. on behalf of the Regional Municipality. In their report released in 1973, the potential yield in a 240 square mile area between the Grand and Nith Rivers was estimated to be 34 MGD.

A review of the report and a further re-evaluation by Ministry staff resulted in a total estimated yield of 34.6 MGD; 22.6 MGD in the Kitchener-Waterloo area and 12.0 MGD in the Cambridge area. The Regional Municipality of Waterloo has a study in progress to review the yield of aquifers in the Cambridge area.

The Ministry's estimates of the availability of ground-water supplies based on the most recent studies may be summarized as follows:

<u>Aquifer System</u>	<u>Estimated Yield of Developed Well Fields</u>	<u>Potential Capacity</u>	<u>Total Capacity</u>
Kitchener-Waterloo	17.6 MGD	5.0 MGD	22.6 MGD
Cambridge	<u>12.0 MGD</u>	<u>Under review*</u>	<u>12.0 MGD</u>
TOTAL	29.6 MGD	5.0 MGD	34.6 MGD

*This is "under review" and there may be some potential available; however, no allowance has been made in the design calculations.

Assuming a linear increase in water demand between 1981 and 1986, the average day demand will equal or exceed the estimated average yield of the acquifiers of 34.6 MGD by 1982. Although short-term mining of these acquifiers is possible, it is not recommended for long periods. Peak daily demands would have to be met by excess pumping and well capacity in many of the well fields.

REQUIREMENTS FROM AYR RESERVOIR

Two of the basic alternatives considered incorporate a reservoir at Ayr as the source of water to complement the available ground-water supply. One alternative suggests ground-water recharge of the water from the reservoir and the other suggests direct supply upon treatment of the reservoir water. Either would be used to complement the well supply system. These systems are shown in figures 1 and 2.

For Ground-Water Supply Plus Ayr Reservoir Recharge

The 1971 Treasury Board report projected an average daily water demand of 69.0 MGD in the year 2001. This amount is used in this report as the design criteria for a system of wells and ground water recharge. Since the wells will be developed to yield the full perennial yield of 34.6 MGD, the remaining 34.4 MGD must be supplied by the recharge scheme. The demands for water from the recharge scheme and from the proposed Ayr Reservoir are as follows:

	<u>1976</u>	<u>1981</u>	<u>1986</u>	<u>1991</u>	<u>1996</u>	<u>2001</u>
MEGALOPOLIS DEMAND (MGD)	27.1	32.9	42.1	51.4	60.3	69.0
AVERAGE DAY FROM RECHARGE SCHEME (MGD)	0	0	7.5	16.8	26.8	34.4
WATER NEEDED FROM AYR RESERVOIR (MGD)	0	0	7.9	17.7	27.1	36.2

For the purposes of design it has been estimated that there will be 95% recovery of the recharged water. This value was used in the calculation of "Water Needed From Ayr Reservoir". This recovery is not a proven value and thus further study and refinement would be required prior to final design.

By 1982 the recharge system must be capable of supplying additional water to the system. The use of average day demand rather than peak days for design of the recharge scheme is justified because the peak demands can be obtained from ground-water storage. These overdrafts will be replenished during subsequent below-average day uses. However, the pumping capacity of the well system to recover the recharged water needs to be capable of meeting peak daily demands of 1.6 times the average demands from the recharge scheme.

For Ground Water Supply Plus
Ayr Reservoir Direct Treatment

Similarly, the requirements from the Ayr Reservoir for direct treatment and supply to complement the available well supply is based on the estimated average water demand of 69.0 MGD in the year 2001. The wells will yield 34.6 MGD and the remaining 34.4 MGD will be obtained from the Ayr Reservoir and treated prior to discharge to the system. The requirements from the reservoir over the design period are summarized as follows:

	<u>1976</u>	<u>1981</u>	<u>1986</u>	<u>1991</u>	<u>1996</u>	<u>2001</u>
MEGALOPOLIS DEMAND (MGD)	27.2	32.9	42.1	51.4	60.3	69.0
AVERAGE DAY WATER REQUIRED FROM AYR RESERVOIR (MGD)	0	0	7.5	16.8	26.8	34.4
MAXIMUM DAY WATER REQUIRED FROM AYR RESERVOIR (MGD)	0	0	12.0	26.9	42.9	56.0

By 1982 the direct system must be capable of supplying water to complement the well supply. As before the ground water system will be capable of meeting peak demands; however, the direct treatment system must have sufficient capacity to supply 1.6 times the average day demands. This was used in the calculation of the "Maximum Day Water Required From the Ayr Reservoir".

AYR RESERVOIR SOURCE OF SUPPLY

RESERVOIR DESCRIPTION

The site of the proposed Ayr Dam is about one mile north of the Highway 401 crossing of the Nith River near the Village of Ayr. The drainage area above the dam is 330 square miles. The proposed dam would be 5500 feet long and 55 feet high at its highest point. The actual construction of the dam could be completed in three years.

The total storage available at the site is 83,130 acre-feet with a maximum reservoir level of 993 feet. The average depth of the reservoir would be 17 feet for a surface area of 4,800 acres. The reservoir would flood lands in Blenheim Township that are presently being used for agricultural purposes.

A preliminary land appraisal indicates that about 9,000 acres of land would be required for the project. Of this amount, about 50 percent is required above the maximum reservoir level to control development adjacent to the reservoir and to avoid leaving land in private ownership without access. Land acquisition would likely involve at least three years, as expropriation and environmental hearings will likely be required. Therefore, the scheduling for the project should allow six years for completion.

Hydro and telephone lines would have to be altered. The gas pipeline south of the river would have to be relocated or protected. Some township and county roads would also have to be closed and Highway No. 97 would have to be relocated for a distance of about 6.5 miles.

RESERVOIR YIELD

Streamflow records are available for the Grand River at Galt from 1913 to the present. Streamflow records are also available for the Nith River near Canning for intermittent periods between 1913 and 1948 and continuously from 1949 to the present. These streamflow records were analysed using a computer program to synthesize outflows from the reservoir.

Some of the basic assumptions used in the analysis are as follows:

- (i) About 23,000 acre-feet of storage would be retained in the reservoir at all times to assist in improving water quality.
- (ii) Water supply storage equals 52,630 acre-feet and in addition 7,500 acre-feet of storage would be reserved for flood control purposes.
- (iii) The reservoir would be drawn down to the minimum holding level at the first of March every year.
- (iv) The minimum flow downstream of the dam would be adequate to maintain historical stream flows during critical low flow periods.

The results of the analysis indicated that the reservoir could be filled each spring. The water supply storage of 52,630 acre-feet will supply the average day demand of 34.4 MGD for a year and the maximum day demand of 56.0 MGD for 80 days in the year 2001. The storage for water supply purposes will be replenished during periods of excess streamflows during the year. Therefore, on the basis of available streamflow records, the year 2001 maximum day demand for direct treatment can be met without interfering with low flows downstream.

FLOOD CONTROL BENEFITS

The Treasury Board Report of 1971 estimated the average annual flood control benefits provided by the Ayr Reservoir to be \$414,000. Allowing for increases in price levels since that time, the average annual flood control benefits as of January 1974 are estimated to be at least \$460,000.

The present value of the flood control benefits provided by the Ayr Reservoir is in the order of \$5,400,000 to \$8,400,000 using discount rates of 8 and 5 per cent respectively and assuming a 50 year life for the dam. The estimated capital cost of the Ayr Dam and Reservoir is \$24,700,000. Therefore, a reasonable division of costs is 25 per cent for flood control purposes and 75 per cent for water supply purposes. This cost sharing has been assumed in the development of the costs for the water supply systems.

TREATMENT STUDIES

From the treatability studies carried out on the Nith River and Lake Conestogo waters it has been established that for removal of colour, turbidity and algae, pretreatment is essential if the water from the Ayr Reservoir is to be used for either (1) direct use, or (2) recharge purposes.

The plant to be used should be comprised of treatment facilities dependent upon the system for which it is selected.

1. For Direct Use

For "direct" use a conventional full treatment water supply plant will be used. However, the treatment studies that have been done for this report will assist in the selection of individual components.

2. For Groundwater Recharge

For "Recharge" purposes, upflow solids contact clarifiers, with rise rate up to 1.25 gpm/sq. ft. without subsequent filtration, would be adequate for the removal of breakdown products, such as algae, to prevent clogging of the recharge beds.

A summary of the treatability study and the data is appended for reference. Also included in the appendix is the results of analyses for sulphates and total dissolved solids.

It is noted that the Hydrology Consultants Ltd. recommended micro-straining; however, the Ministry considers upflow-clarification a more viable method of pretreatment.

GROUNDWATER RECHARGE FEASIBILITY STUDIES

In 1972, the Ministry undertook to determine the physical and economic feasibility of artificial ground water recharge as an alternative means of providing municipal water supplies for the Megalopolis of Kitchener, Waterloo and Cambridge to the year 2001. This undertaking relates directly to RECOMMENDATION 21 in the Treasury Board report of 1971.

Soils testing was carried out during 1972 in a broad area between Kitchener and Ayr and resulted in defining five smaller target areas in which geologic conditions warranted further testing of the feasibility of ground water recharge (Figure 3). These areas, were, in the order of priority:

- (i) Roseville
- (ii) Ayr
- (iii) Orr's Lake
- (iv) Mannheim
- (v) Wilmot Township northeast of Baden

Feasibility studies were undertaken in 1973 by Hydrology Consultants Ltd. on behalf of the Ministry. The area in Wilmot Township was not studied because of its remoteness from the proposed Ayr Reservoir and because of monetary and time limitations in the study. Work in the Mannheim area was also of limited scope due to similar restrictions on available time and budgetary allocations in the remainder of the work. Work in Roseville, Ayr and Orr's Lake areas was extensive and consisted of detailed test drilling, sub-surface formation sampling and hydraulic testing to pinpoint specific sites suitable for recharge.

The results of these investigations are documented in a report entitled "Grand River Basin-Artificial Recharge Feasibility Study-1974", by Hydrology Consultants Ltd. The consultant indicates that the Roseville target area is considered suitable for artificial recharge and that the Mannheim area appears to be suitable, provided certain assumptions based on the past year's study are verified.

Field measurements of permeability during a 15 day infiltration test in the eastern part of the Roseville area indicated a relatively high permeability (1×10^{-1} cm/sec) in the saturated portion of the near-surface sand and gravel at the site. This permeability has been used in the design of the recharge scheme. Permeabilities in boreholes near the infiltration basin calculated by the Hazen method from grain-size analyses were three to five times less than the value obtained during the infiltration test. Based on this difference the consultant increased the permeability estimates calculated by the Hazen method for all boreholes by a factor of three. After this adjustment, the permeability estimates for three boreholes near the infiltration site ranged from about 4×10^{-2} to 6×10^{-2} cm/sec and were in the mid-range of the adjusted estimates of 2×10^{-2} to 8×10^{-2} cm/sec for many of the boreholes in the Roseville area.

Because of the variations in the permeability estimates, further work would be required to determine applicable permeabilities in areas designed for ground water recharge and recovery. Considerable work is needed in the Mannheim area to verify the continuity of the aquifer to be recharged, as well as obtain reliable estimates of permeabilities in the aquifer. In order to provide these basic answers in both the Roseville and Mannheim area, the consultant estimates that a period of about 2.5 years, at an approximate cost of \$460,000 is required for further work.

The total recharge scheme will be designed for a 36 MGD recharge capacity, of which 20 MGD is designed to be infiltrated at Roseville and 16 MGD at Mannheim. These recharge amounts are only preliminary estimates of the distribution between the two areas.

The conceptual design of the recharge operation at Roseville consists of conveying pretreated Ayr Reservoir water to three separate areas of infiltration basins. A schematic recharge model is shown in Figure 4. The model assumes a retention of water in the ground for 100 days and the minimum infiltration in the basins is about 8 feet of water per day. A total of 9 acres of infiltration basins will recharge an average of 20 MGD throughout the year. Some basins will be used for standby when cleaning of basins is necessary. The recharged water will be recovered through 75 wells, each with an assumed pumping capacity of approximately 0.5 MGD. The recovered water will be collected in a 5 million gallon reservoir near Roseville and then pumped to the municipality.

The geologic conditions in the Roseville area are varied and the drilling completed to date indicates that a number of sites differ from the conceptual model. Also, the conditions in the eastern part of the area north of Highway 401 were not tested by drilling.

It should be noted that highways 401 and 97 are located in the recharge area and both carry a variety of commercial traffic, including tanker trucks. Consequently, the potential hazard of contaminating ground water by liquid pollutants should be a consideration in the final design of the recharge schemes.

The recharge scheme at Mannheim has not been detailed to date but will consist basically of infiltration of pretreated reservoir water in surface basins in an area of surface gravels east of Mannheim. The water will be recovered in wells and it is expected that virtually all of the recharged water can be captured. Further testing of hydrogeologic continuity and aquifer hydraulics in light of a recharge system would be required before the final design of recharge basins and recovery wells. The estimate of cost of the capital works in the scheme has been based on the general concept of recharge at Roseville, and the costs were proportioned, where applicable, to the Mannheim scheme.

Considerably more information would be needed before a final decision could be made on the feasibility and actual cost of the recharge project. More exact hydrogeologic data are needed on permeability values at specific sites of recharge basins and recovery wells, pumping tests are necessary to evaluate

the efficiency and different methods of recovery, and a number of aspects of the conceptual models must be verified through pilot studies. These data are needed both at Roseville and Mannheim and Hydrology Consultants Ltd. has proposed two phases of work in each area prior to a final decision on the feasibility of the scheme:

1. Test drilling to define exact sites for recharge basins and recovery wells, and
2. Pilot studies in each area prior to final design.

Mathematical modelling of the recharge schemes is also forseen. Although the schedule of work indicated by Hydrology Consultants Ltd. indicates work to start in 1974, it is expected that time required for an environmental assessment of the recharge scheme and other water supply options, and arrangements for financing would likely delay the beginning of further testing until 1975.

- | | |
|-------|---|
| 1975- | <ol style="list-style-type: none">1. Test drilling at Roseville (3 months)2. Test drilling at Mannheim (3 months)3. Beginning Pilot Study at Mannheim (2 months) |
| 1976- | <ol style="list-style-type: none">1. Continuation of Mannheim Pilot study (5 months)2. Pilot Study at Roseville (8 months)3. Mathematical Modelling at Roseville and Mannheim (5 months total) |
| 1977- | <ol style="list-style-type: none">1. Test drilling at Roseville (or Mannheim) for basin and recovery well sites (6 months)2. Refined mathematical model at Roseville (1 month)3. Begin final design for Roseville |

The above schedule and associated expenditure are considered to represent the minimum time and cost that would be required for testing.

LAKE SOURCES OF SUPPLY

Three lake oriented water supply schemes have been suggested to serve the Kitchener-Waterloo-Cambridge area. The three sources are Lake Erie, Lake Ontario and Lake Huron (see figures 5 and 6). For each alternative a major water treatment plant would be constructed at the lake and then piped to the service area.

If one of the sources is selected, an extensive sampling and testing program would be undertaken at the intake location before final design is commenced to accurately determine the most economical manner of treatment required to achieve potable water of high quality. Regardless of the source, the finished water quality from these three sources will be virtually identical. Most of the water treatment plants in operation using Lake Erie, Huron and Ontario as a raw water source utilize the conventional form of treatment. It is on the basis of this that the cost estimates for treatment have been made.

For the Lake Erie scheme the comparative costs for three service areas have been developed.

The lake supply systems with the respective service areas are summarized below:

1. Lake Erie Schemes - Intake Location Near Nanticoke

(a)	Service Areas	-Stelco (potable), Texaco, Stelco's proposed Industrial Park, Caledonia, Cayuga, Hagersville, Jarvis, the Townsend new town proposed by the Provincial Government, Brantford, Cambridge, Kitchener and Waterloo (Port Dover is assumed to continue on its own water supply and is thus excluded).
	Year 1996 Population	-748,000
	Year 2001 Population	-859,000
(b)	Service Area	-For purposes of comparison, a scheme serving only the Nanticoke area and Brantford was costed. The source of supply and location of the water works are the same as the Lake Erie scheme. The difference arises in the exclusion of the Kitchener-Waterloo-Cambridge area.
	Year 1996 Population	-260,000
	Year 2001 Population	-284,000

(c) Service Area	-To provide a further comparison, the possibility of serving only the Kitchener-Waterloo-Cambridge area from Lake Erie was explored. The capital costs were pro-rated on the basis of flow.
------------------	---

Year 1996 Population	-488,000
----------------------	----------

Year 2001 Population	-575,000
----------------------	----------

2. Lake Ontario Scheme

Source of Supply	-Lake Ontario
------------------	---------------

Intake Location	-Port Nelson area of Burlington
-----------------	---------------------------------

Service Area	-Kitchener, Waterloo and Cambridge
--------------	------------------------------------

Year 1996 Population	-488,000
----------------------	----------

Year 2001 Population	-575,000
----------------------	----------

3. Lake Huron Scheme

Source of Supply	-Lake Huron
------------------	-------------

Intake Location	-Approximately ten miles south of Bayfield
-----------------	--

Service Area	-Kitchener, Waterloo and Cambridge
--------------	------------------------------------

Year 1996 Population	-488,000
----------------------	----------

Year 2001 Population	-575,000
----------------------	----------

COST ESTIMATES

COST CRITERIA

Some of the basic criteria used in the development of the cost estimates are listed below:

1. The cost of land purchases and easements has been included at the following rates.
 - (a) Pipelines - \$1500 per Acre (with 60 or 100 foot wide easements)
 - (b) Recharge Scheme - local costs ranging from \$1000 to \$30,000 per acre have been used (60 foot wide pipeline easements).
2. The costs are estimated in January 1974 dollars and based on a borrowing rate of 9.5 per cent.
3. A 25 percent allowance for engineering and contingencies is included.
4. No internal distribution system costs were calculated for any of the alternatives considered (i.e. local water distribution works will remain the responsibility of the respective existing authority).
5. For the surface water systems the annual operation and maintenance costs of the pipelines and intakes were estimated to be $\frac{1}{4}$ percent of accumulated capital cost.
6. Also, for the surface water systems the annual operation and maintenance costs of the pumping stations and storage facilities were estimated to be $\frac{1}{2}$ percent of the accumulated cost.
7. For the ground water supply plus Ayr Reservoir recharge scheme, the operation and maintenance charges for the surface water treatment plant, the wells, basins and the reservoir were calculated separately. The operation and maintenance cost of the wells were estimated at 5 cents for 1000 gallons and 1 cent per 1000 gallons for the basins.
8. The current operation and maintenance rate of 11 cents per 1000 gallons for Regional Waterloo has been applied to all existing and proposed wells.
9. The costs of softening both Ayr Reservoir and ground water by 200 ppm were based on a California Study which suggested \$15.00/acre feet/100 ppm. (Central and West Basin Water Replenishment Study 1970). This value is not only the expenditure required to provide softening but also assigns a value to the benefits that the consumer realizes from softened water.
10. The annual production cost for the direct supply of water from the Ayr Reservoir have been increased by 10 per cent to allow for control of taste and odours of the impounded waters.
11. Capital costs for pumping stations, treatment plants, storages and intakes were estimated from graphs previously developed by the OWRC.

Two financial analyses were performed on each alternative for the initial 20-year period beginning in 1976 and ending in 1995: one based on a two-stage program (ten years apart) and a second based on three stages (in the event that the expenditure for the third stage occurs in the 20th year rather than the 21st year). The analyses are based on the population projections outlined in Table 1 and the water consumption projections contained in Table 2.

The service rate per 1,000 gallons was calculated to cover capital debt retirement, interest charges and operation and maintenance costs. These financial analyses were based on a 40-year financing period and were carried out on the assumption that a 15 per cent subsidy by the Province of Ontario would be applied to the gross capital cost of each stage on the area schemes rather than to stage one only. This assistance was incorporated on the assumption that the Province would be requested to finance and operate the system.

For comparison of the capital investment involved, the present net worth values have been developed. Based on a discount rate of $9\frac{1}{2}$ per cent the capital costs, land costs and operation and maintenance costs have been calculated as present net worth values. The 15 per cent Provincial subsidy that may be applied has not been considered in these calculations. For comparison, a summary of the total capital cost, the service rate estimates, and the present net worth value for the three stage costs for each alternative is presented in Table 3. Since there was only a minimal cost difference between the two and three stage proposals (approximately 0.1 cents per 100 gallons) only the 3-stage costs are shown.

The following sections discuss the capital and operation and maintenance costs for each alternative. The capital costs (not including land) include the 25 per cent allowance for engineering and contingency.

AYR RESERVOIR

The estimated cost of the Ayr Dam and Reservoir project including land acquisition, construction and a 25 per cent allowance for engineering and contingency is \$24.7M. The annual operating costs for the dam are estimated to be 0.3 per cent of the capital costs of the dam which equals \$39,400. Seventy-five per cent of the capital cost is assigned to the water supply scheme for the Regional Municipality of Waterloo.

Capital Cost of Ayr Dam and Reservoir	\$24,700,000
75% charged to water supply scheme	\$18,525,000
Annual operating costs (at 0.3 per cent)	\$ 39,000

GROUND WATER SUPPLY PLUS AYR RESERVOIR DIRECT TREATMENT

Capital cost estimates have been developed as listed below:

	<u>1976</u>	<u>1986</u>	<u>1996</u>	<u>Total</u>
1. Ayr Reservoir cost attributed to the water supply	\$18.525*M	----	----	
2. Supply and treatment of water from reservoir	\$13.649 M	\$15.388 M	\$7.338 M	
3. New Well Development	\$ 2.149 M	----	----	
4. Right-of-Way Cost	\$.260 M	----	----	
TOTALS	\$34.583 M	\$15.388 M	\$7.338 M	\$57.309 M

*Note: "M" represents one million dollars

The annual operation and maintenance costs have been calculated for a number of individual years within the design period and the costs for the intervening years were interpolated for use in the financial analysis. Included within these costs are the annual costs for production, power, pipeline maintenance, pumping station and storage maintenance, well operation and maintenance and the Ayr Reservoir operation and maintenance.

Operation and Maintenance (Ground and Surface Water)

<u>Year</u>	<u>Total (without softening)</u>	<u>Annual Softening of Ground and Surface Waters</u>	<u>Total (with softening)</u>
1976	\$1,121,900	\$1,092,900	\$2,214,800
1985½	1,749,200	1,695,900	3,445,100
1986	1,709,600	1,695,900	3,405,500
1995½	2,215,200	2,430,200	4,645,400
1996	2,103,400	2,430,200	4,593,600

GROUND WATER SUPPLY PLUS AYR RESERVOIR RECHARGE

Cost estimates shown for pilot studies and for construction of wells and recharge basins have been calculated by Hydrology Consultants Ltd., supplemented by estimates derived by Ministry staff. The cost estimates for operation and maintenance of wells and basins and for future testing and pilot schemes are as provided by the consultant. Capital cost estimates for basin construction are as calculated by the consultant, but the construction costs have been revised by the Ministry and additional costs associated with land and easement purchases have been included. The staging of capital expenditures is according to a tentative schedule of construction of the recharge scheme:

1976	Pilot Study, plus half Roseville Scheme (10 MGD)
1986	Half Roseville Scheme (10 MGD) plus half Mannheim Scheme (8 MGD)
1996	Half Mannheim Scheme (8 MGD)

The capital cost estimates are summarized on the following page.

	<u>1976</u>	<u>1986</u>	<u>1996</u>	<u>Total</u>
1. Ayr Reservoir cost attributed to water supply	\$18.525 M	----	----	
2. Pretreatment and Supply from reservoir and recharge cost	\$11.872 M	\$11.855 M	\$2.568 M	
3. Pilot Study cost	\$.460 M	----	----	
4. Land Costs	\$.923 M	----	----	
5. New Well Development	\$ 2.149 M	----	----	
TOTALS	\$33.929 M	\$11.855 M	\$2.568 M	\$48.352 M

The annual operation and maintenance costs have been calculated including the annual operation and maintenance costs for pretreatment, groundwater supply, recharge system, and the Ayr Reservoir.

Operation and Maintenance (Ground and Recharge)

<u>Year</u>	<u>Total (without softening)</u>	<u>Annual Softening of of Ground and Recharge Waters</u>	<u>Total (with softening)</u>
1976	\$1,123,000	\$1,092,900	\$2,215,900
1985½	1,708,400	1,695,900	3,404,300
1986	1,774,000	1,695,900	3,469,900
1995½	2,403,100	2,430,200	4,833,300
1996	2,440,800	2,430,200	4,871,000

LAKE PIPELINE SYSTEMS

The lake oriented pipeline systems and the respective service areas that have been costed are as follow:

1. Lake Erie - Nanticoke/Brantford/KWC
2. Lake Erie - Nanticoke/Brantford
3. Lake Erie - Kitchener/Waterloo/Cambridge only
4. Lake Ontario - Kitchener/Waterloo/Cambridge only
5. Lake Huron - Kitchener/Waterloo/Cambridge only

The capital costs have been summarized for the influent works, the treatment and supply and the land charges. The annual operation and maintenance costs include the annual charges for production, power, intake and pipeline maintenance and pumping station and storage maintenance.

The costs are summarized on the following page in a manner similar to that used earlier.

1. Lake Erie - Nanticoke/Brantford/KWC

<u>Capital Costs</u>	<u>1976</u>	<u>1986</u>	<u>1996</u>	<u>Total</u>
1. Influent Works	\$ 1.679 M	----	----	
2. Treatment and Supply	\$114.623 M	\$28.393 M	\$15.673 M	
3. Land Charges	\$ 1.236 M	-----	-----	
TOTALS	\$117.538 M	\$28.393 M	\$15.673 M	\$161.604 M

Operation and Maintenance

1976	\$1,222,000
1985½	\$1,653,600
1986	\$1,864,000
1995½	\$2,551,500
1996	\$2,681,800

2. Lake Erie - Nanticoke/Brantford

<u>Capital Costs</u>	<u>1976</u>	<u>1986</u>	<u>1996</u>	<u>Total</u>
1. Influent Works	\$.331 M	----	----	
2. Treatment and Supply	\$39.177 M	\$20.980 M	\$7.005 M	
3. Land Charges	\$.681 M	-----	-----	
TOTALS	\$40.189 M	\$20.980 M	\$7.005 M	\$68.174 M

Operation and Maintenance

1976	\$ 487,000
1985½	\$ 731,700
1986	\$ 623,800
1995½	\$1,029,300
1996	\$1,044,200

3. Lake Erie - KWC Only

<u>Capital Costs</u>	<u>1976</u>	<u>1986</u>	<u>1996</u>	<u>Total</u>
1. Influent Works	\$ 1.175 M	----	----	
2. Treatment and Supply	\$78.734 M	\$17.411 M	\$9.118 M	
3. Land Charges	\$.711 M	-----	-----	
TOTALS	\$80.620 M	\$17.411 M	\$9.118 M	\$107.149 M

Operation and Maintenance

1976	\$ 825,800
1985½	\$1,117,400
1986	\$1,238,200
1995½	\$1694,200
1996	\$1,780,700

4. Lake Ontario - KWC

<u>Capital Costs</u>	<u>1976</u>	<u>1986</u>	<u>1996</u>	<u>Total</u>
1. Influent Works	\$ 2.802 M	----	----	
2. Treatment and Supply	\$78.709 M	\$16.890 M	\$7.664 M	
3. Land Charges	\$.663 M	-----	-----	-----
TOTALS	\$82.174 M	\$16.890 M	\$7.664 M	\$106.728 M

Operation and Maintenance

1976	\$1,132,800
1985½	\$1,487,300
1986	\$1,599,000
1995½	\$2,001,800
1996	\$2,099,100

5. Lake Huron - KWC Only

<u>Capital Costs</u>	<u>1976</u>	<u>1986</u>	<u>1996</u>	<u>Total</u>
1. Influent Works	\$ 3.037 M	----	----	
2. Treatment and Supply	\$99.927 M	\$20.046 M	\$8.586 M	
3. Land Charges	\$ 1.095 M	-----	-----	-----
TOTALS	\$104.059 M	\$20.046 M	\$8.586 M	\$132.691

Operation and Maintenance

1976	\$1,145,800
1985½	\$1,487,900
1986	\$1,680,000
1995½	\$2,090,900
1996	\$2,242,500

CONCLUDING STATEMENT

From the foregoing, it appears that the two alternatives which are the most attractive from the economic point of view are those which utilize water from the Ayr Reservoir to augment available ground water supplies either directly or through a system of recharge. Because of the variables associated with artificial recharge systems, the cost estimates of this alternative are the most questionable of those presented. As the cost estimates for the two Ayr Reservoir alternatives are fairly similar, further study of some of their costs by a consultant may be warranted.

Of the lake oriented alternatives, the Lake Erie system is the most attractive. However, it must be realized that each alternative has its own advantages and disadvantages. Therefore, in comparing the costs outlined in Table 3, intangibles should be carefully considered. For example, in arriving at a final conclusion, an environmental assessment would be undertaken to identify socio-economic benefits and the effect of the various alternatives on ecology and adjacent land uses. Since this study has not attempted to deal with these matters, no specific recommendations are presented.

TABLE 10.10. 1974-1975 BUDGETARY TRANSFERS TO STATES

The following table shows the amount of money that the federal government transferred to the states in 1974, 1975, and 1976. The amounts are in billions of dollars.

TABLE 10.10. 1974-1975 BUDGETARY TRANSFERS TO STATES

	1974	1975	1976	Change from 1974 to 1975
Total Transfers	112	100	100	-12
- for highways	118	100	100	-18
- for education	100	100	100	0
- for health	10	100	10	90
- for other	0.2	100	0.2	99.8
- for other	10	100	10	90
- for other	0.2	100	0.2	99.8
- for other	10	100	10	90
- for other	0.2	100	0.2	99.8
- for other	10	100	10	90

APPENDIX A

TABLE 10.10. 1974-1975 BUDGETARY TRANSFERS TO STATES

	1974	1975	1976	Change from 1974 to 1975
Total Transfers	112	100	100	-12
- for highways	118	100	100	-18
- for education	100	100	100	0
- for health	10	100	10	90
- for other	0.2	100	0.2	99.8
- for other	10	100	10	90
- for other	0.2	100	0.2	99.8
- for other	10	100	10	90
- for other	0.2	100	0.2	99.8
- for other	10	100	10	90

GRAND RIVER BASIN RECHARGE TREATABILITY STUDY

The treatability studies conducted on water from the River Nith and Lake Conestogo from May, 1973 to March, 1974, are summarized as follows:

River Nith raw water analysis

	<u>Av.</u>	<u>High</u>	<u>Low</u>	
Total Hardness	298	400	102	Mg/l as CaCO_3
(Ca) Hardness	219	295	82	Mg/l as CaCO_3
Total Alkalinity	193	260	80	Mg/l as CaCO_3
Chlorides	30	100	16	Mg/l as Cl
Total Iron	0.1	0.2	0.02	Mg/l as Fe
Colour	34	125	10	Hazen Units
pH	8.1	8.35	7.95	Units
Turbidity	28	200	2.2	FTU

Lake Conestogo raw water analysis

	<u>Av.</u>	<u>High</u>	<u>Low</u>	
Total Hardness	216	270	148	Mg/l as CaCO_3
(Ca) Hardness	153	212	110	Mg/l as CaCO_3
Total Alkalinity	181	210	120	Mg/l as CaCO_3
Chlorides	25	100	12	Mg/l as Cl
Total Iron	0.06	0.1	0.02	Mg/l as Fe
Colour	25	40	10	Hazen Units
pH	8.3	8.75	8.0	Units
Turbidity	15	72	1.6	FTU

Chemical dosages as per treatability studies

<u>River Nith</u>	<u>Av.</u>	<u>High</u>	<u>Low</u>
Aluminum Sulphate	40	65	25 Mg/l
Activated Silica	3	6	2 Mg/l
Sulphuric Acid	29	42	16 Mg/l

<u>Lake Conestogo</u>	<u>Av.</u>	<u>High</u>	<u>Low</u>
Aluminum Sulphate	35	40	30 Mg/l
Activated Silica	3	4	2 Mg/l
Sulphuric Acid	29	38	16 Mg/l

Average analysis of supernatant and filtered water taken from jar tests

River Nith

Supernatant	- Total Alkalinity	120	Mg/l
	- Colour	< 5	Hazen Units
	- pH	6.9	Units
	- Turbidity	1.6	FTU
	- Residual Aluminum	0.69	Mg/l
Filtered Water	- Total Alkalinity	175	Mg/l
	- Colour	< 5	Hazen Units
	- pH	7.3	Units
	- Turbidity	0.14	FTU
	- Res. Aluminum	0.06	Mg/l

Lake Conestogo

Supernatant	- Total Alkalinity	110	Mg/l
	- Colour	< 5	Hazen Units
	- pH	7.0	Units
	- Turbidity	2.65	FTU
	- Res. Aluminum	0.35	Mg/l
Filtered Water	- Total Alkalinity	130	Mg/l
	- Colour	< 5	Hazen
	- pH	7.4	Units
	- Turbidity	0.02	FTU
	- Res. Aluminum	0.07	Mg/l

From the treatability studies carried out on the River Nith and Lake Conestogo waters it has been established that for the removal of colour, turbidity and algae, pre-treatment is essential if the water from either of these sources is to be used for:

- (1) Direct use or
- (2) Recharge purposes

In this regard it is suggested that the plant should comprise treatment depending on the system for which it is selected. Our recommendations are as follows:

1. For "Direct" use the plant should comprise: upflow solids contact clarifiers followed by filtration. For economic reasons the filters can be rated for 5 gpm/sq ft.
2. For "Recharge" purposes, upflow solids contact clarifiers, with rise rate up to 1.25 Igpm/ft without subsequent filtration, would be adequate for the removal of breakdown products, such as algae, to prevent clogging of the recharge beds.

Sludge Production (based on 35 MGD operation)

Based on the average raw water analysis from the River Nith having a turbidity of 28 mg/l (assumed as a weight) and being treated with average chemical dosages of 40 mg/l of aluminum sulphate and 3 mg/l of activated silica, it is estimated that the sludge production in the clarifiers would be:

Sludge per million gallons	=	347 lb
1% slurry per " "	=	3470 gallons
Sludge at 35 MGD	=	12145 lb
1% slurry at 35 MGD	=	121450 gallons

With respect to the treated water quality for filling the recharge basins, no calcium carbonate saturation problems would be involved as might have been present with the water before treatment. Alum additions between 25 and 65 mg/l would result in alkalinity reductions of 12.5 and 32.5 mg/l CaCO_3 respectively. Against the initial pH range of 7.8 to 8.4 for the raw water, the treated water would therefore range from 7.1 to 7.6. These limits are all lower than the Jacobson & Langmuir pH saturation values ranging between 7.64 to 8.18 cited last September 17, 1973. The Langelier Index saturation pH for calcium carbonate ranged from 7.15 to 7.85, but Langelier data were reputed not to be as reliable as the newer Jacobson and Langmuir findings.

Additionally, far less algal regrowth problems with any attendant pH increases in the recharge basins are likely with the alum treated supply. Alum treatment would minimize essential phosphate levels to less than 5 to 10 ppb for a very low algal growth potential.

Concentrations of sulphates and total dissolved solids were not included in the Nith River treatability study but separate analyses conducted during the summer of 1973 indicated that these parameters were relatively high in the Nith River. Sulphate concentrations at three separate stations in the vicinity of the Ayr Reservoir ranged between 37 and 130 ppm and total dissolved solids varied from 350 to 560 ppm. The Ministry's desirable criteria for sulphates and total dissolved solids are less than 50 and less than 200 ppm respectively, and the permissible criteria are 250 and 500 ppm respectively.

TABLE 1: POPULATION PROJECTIONS 1976 - 1996

Year	Total Population	KWC Population	Nanticoke-Brantford Pop'In
1976	318,260	243,000	75,260
1977	330,258	252,200	78,328
1978	342,796	261,400	81,396
1979	355,064	270,600	84,464
1980	367,332	279,800	87,532
1981	379,600	289,000	90,600
1982	400,980	304,000	96,980
1983	422,360	319,000	103,360
1984	443,740	334,000	109,740
1985	465,120	349,000	116,120
1986	486,500	364,000	122,500
1987	512,900	378,800	134,100
1988	539,300	393,600	145,700
1989	565,700	408,400	157,300
1990	592,100	423,200	168,900
1991	618,500	438,000	180,500
1992	644,400	448,000	196,400
1993	670,300	458,000	212,300
1994	696,200	468,000	228,200
1995	722,100	478,000	244,100
1996	748,000	488,000	260,000

TABLE 2: ANNUAL WATER CONSUMPTION PROJECTIONS 1976 - 1996

Year	Total (MG)	KWC (MG)	Nanticoke Area-Brantford (MG)
1976	14,382.9	9,901.7	4,481.2
1977	14,990.5	10,320.0	4,670.5
1978	15,609.3	10,740.9	4,868.4
1979	16,231.1	11,163.5	5,067.6
1980	16,885.2	11,588.0	5,267.2
1981	17,484.0	12,015.1	5,468.9
1982	18,558.4	12,679.4	5,879.0
1983	19,637.3	13,346.9	6,290.4
1984	20,719.7	14,016.8	6,702.9
1985	22,001.7	14,689.0	7,312.7
1986	22,896.4	15,364.7	7,531.7
1987	24,214.1	16,042.5	8,171.6
1988	25,535.1	16,722.5	8,812.6
1989	26,859.4	17,404.7	9,454.7
1990	28,187.8	18,089.8	10,098.0
1991	29,523.0	18,776.7	10,742.3
1992	31,019.9	19,418.7	11,601.2
1993	32,524.7	20,064.0	12,460.7
1994	34,033.5	20,712.0	13,321.5
1995	35,546.7	21,363.5	14,183.2
1996	37,282.3	22,018.0	15,045.3

TABLE 3: COMPARATIVE COSTS

Alternative	Total Capital Cost	Service Charge (cents/1000 gal.)	Present Net Worth
1a Ground Water + Ayr Reservoir Direct Treatment	\$57.309 M	36.6	\$55.544 M
1b Same with softening included	----	48.6	\$69.063 M
2a Ground Water + Ayr Reservoir Recharge	\$48.352 M	35.3	\$52.894 M
2b Same with softening included	----	47.1	\$66.413 M
3a Lake Erie N/B/KWC	\$161.604 M	60.8	\$145.804 M
3b Lake Erie N/B	\$68.174 M	67.7	\$55.501 M
3c Lake Erie KWC	\$107.149 M	61.4	\$98.698 M
4 Lake Ontario KWC	\$106.728 M	65.2	\$102.759 M
5 Lake Huron KWC	\$132.691 M	79.5	\$126.372 M

FIG. 1 GROUND-WATER SUPPLY PLUS AYR RESERVOIR DIRECT
TREATMENT ALTERNATIVE

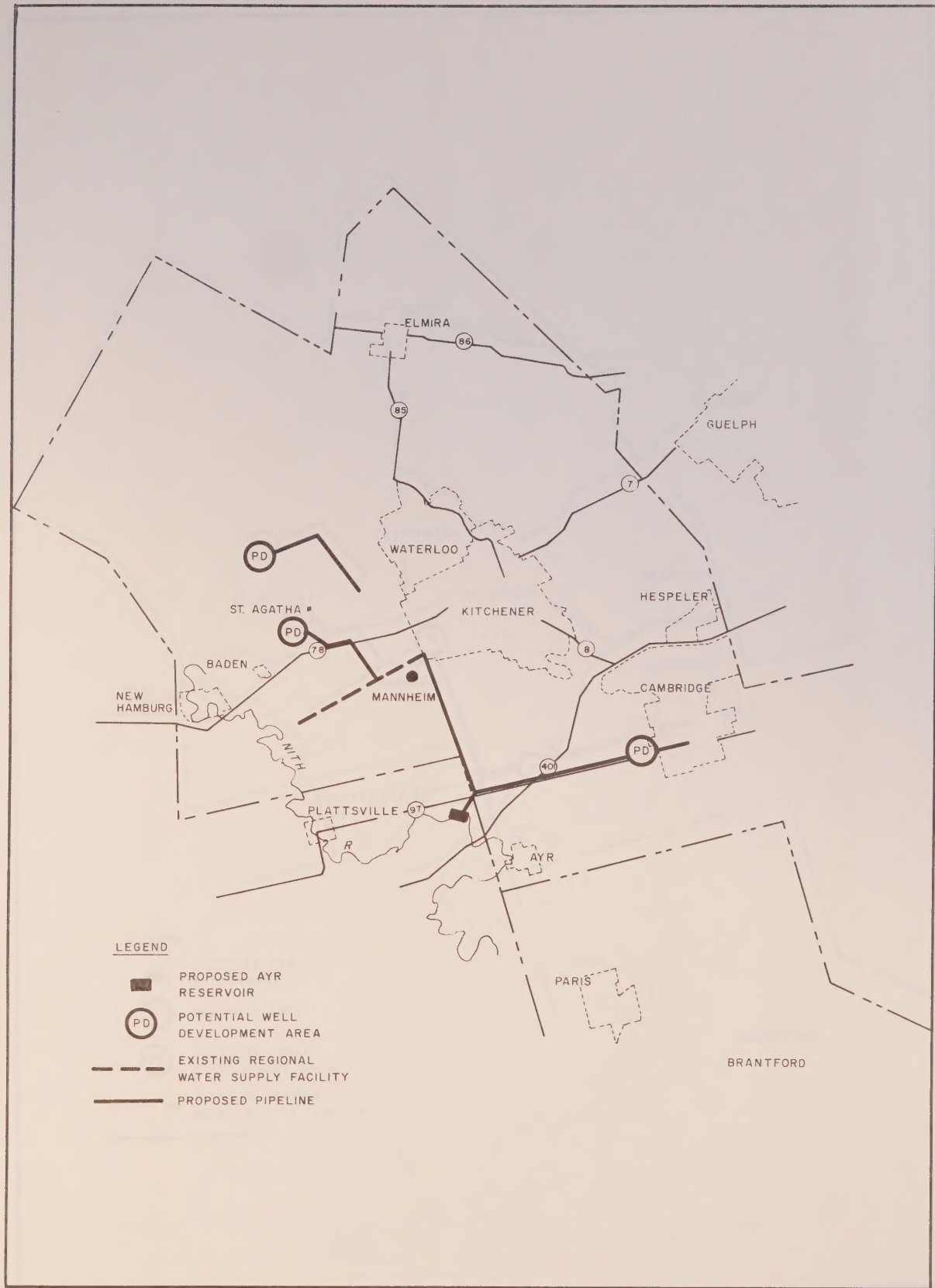


FIG. 1 GROUND - WATER SUPPLY PLUS AYR RESERVOIR DIRECT TREATMENT ALTERNATIVE

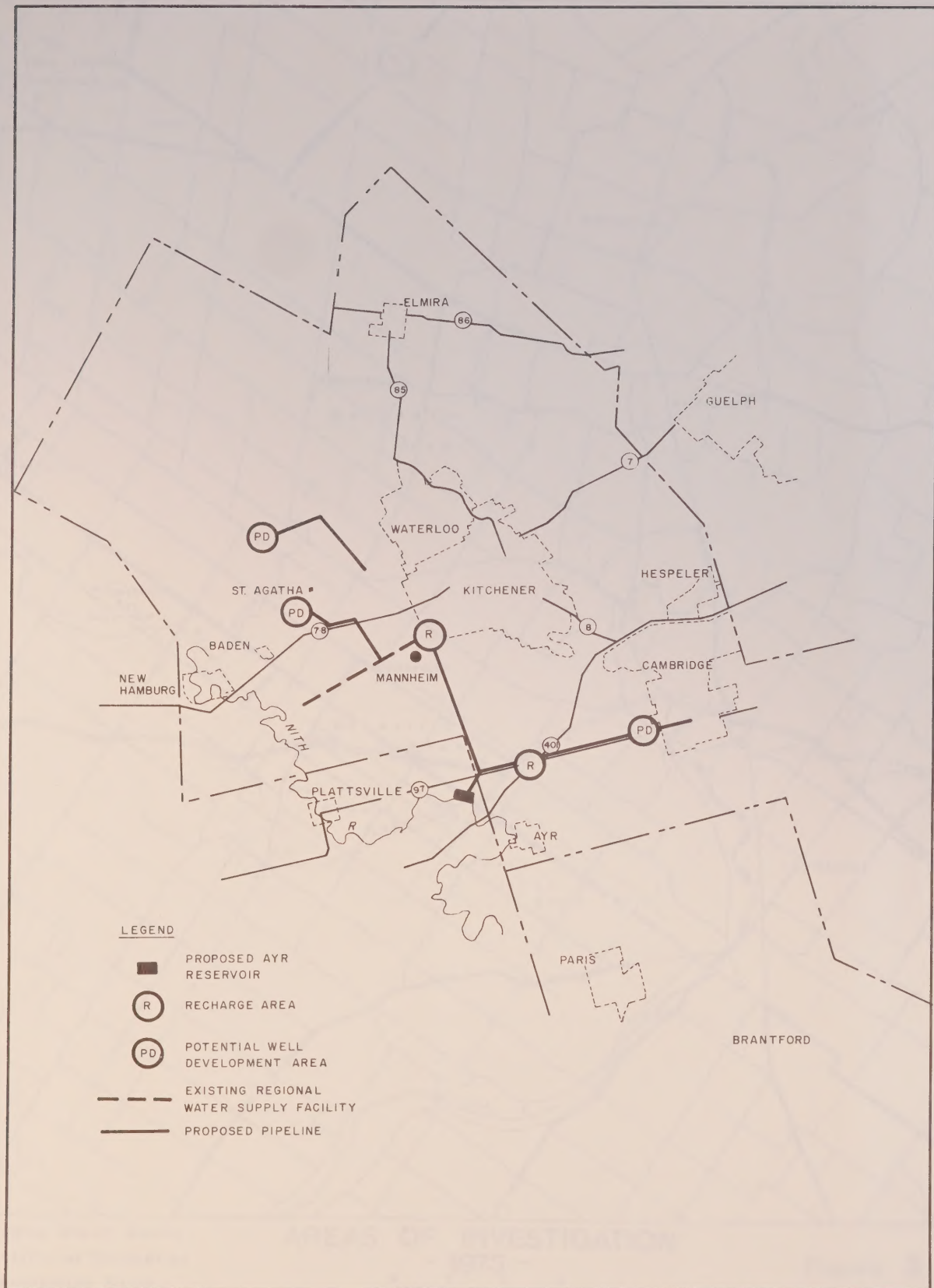


FIG. 2 GROUND - WATER SUPPLY PLUS AYR RESERVOIR RECHARGE ALTERNATIVE



Grand River Basin
Artificial Recharge
Feasibility Study

AREAS OF INVESTIGATION

- 1973 -

0 1 2 3 miles
Scale

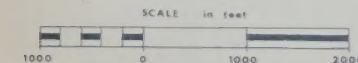
Figure 3



LEGEND

-  Schematic Representation of Infiltration Basins
-  Schematic Representation of Recovery Wells
-  Elevation Contour (Contour Interval 10 Feet)
-  Section Line of Figures 15 and 16

NOTE: For other symbols refer to National Topographic map series A851.



MINISTRY OF THE ENVIRONMENT Grand River Basin Artificial Recharge Feasibility Study

Roseville Area Recharge Model Location Map

HYDROLOGY CONSULTANTS LIMITED
1125 Dundas Street E. Mississauga, Ontario

Job Number 8272	Designed by	Drawn by <i>[Signature]</i>
Checked by	Date February 1974	

FIGURE 4



FIG. 5 PIPELINE WATER SUPPLY SYSTEM - LAKE ERIE ALTERNATIVE
AND LAKE ONTARIO ALTERNATIVE

LEGEND

- PROPOSED WATER TREATMENT PLANT 
- PROPOSED PIPELINE 



FIG. 6 PIPELINE WATER SUPPLY SYSTEM - LAKE HURON ALTERNATIVE



